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ABSTRACT

A summary and discussion of a series of studies considered the dilemma that equal educational treatment of all children in public schools appears likely to increase the spread of differences among them in educational achievement. Longitudinal studies of pairs of identical and of fraternal twins in Sweden from 10 to 18 years of age considered the similarity within pairs in height and in weight over a span of six years for girls and eight years for boys. Similar studies of correlations in test scores for verbal, mathematical, inductive reasoning, and perseveration abilities led to the conclusion that the achievement tests showed more environmental and less genetic influence than the aptitude tests. Studies of achievement test results in relation to socioeconomic levels showed a large decline from third to sixth grade in the correlation for fraternal twins in the lower socioeconomic group but not for identical twins and not for twins in the higher socioeconomic groups. The studies proposed mastery learning as a method for attaining equality of learning outcomes and concluded that genetic and environmental effects and their interactional and correlational effects can be manipulated by varying environmental permissiveness or restrictedness. (CTM)

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A longitudinal study of twins.

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Abstract

Data concerning physical growth, mental ability and school achievement test results have been collected for MZ and DZ twin pairs and a group of controls from 10 to 18 years of age. A model for interpreting heredity-environment contribution on the basis of longitudinal twin data is presented. Interactional and correlational effects are hypothesized to vary depending upon type of characteristic studied and the permissiveness-restrictedness of environmental factors.

For height growth and inductive ability a parallel trend is found for intrapair similarity in MZ and DZ twins over a time period. This would imply that these characteristics tend to be primarily controlled by genetic factors. Weight growth, especially for girls, verbal ability and school achievement test results, on the other hand, seem to be more susceptible to interactional and correlational influences, indicating that different genotypes will be affected and react differently to a similar environmental impact.

A study of intra-pair similarity of MZ and DZ twins in different social groups leads to somewhat different results for the mental ability tests in comparison to school achievement test results. When all children are exposed to a similar treatment at school, interactional and correlational effects seem to be most conspicuous for children from social group III. For mental ability test results, on the other hand, a more stimulating environment will contribute to a larger intra-pair discrepancy between MZ and DZ twins in social group I in comparison with social group III. Earlier twin studies have generally interpreted interactional and correlational effects as genetic variance and therefore tended to overestimate such influences. The results of this study seem to imply that a similar treatment in a permissive environment will lead to larger differences and that such effects will be most conspicuous for children from working class homes.

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Siv Fischbein

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A Longitudinal Study of Twins

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Finally, I am well aware that a favourable combination of environmental permissiveness and restrictedness both at work and at home has been a pre-requisite for the completion of this work.

February 1979

Siv Fischbein

Salon Gablin

- Which is most important, inheritance or environment?
- It depends on the size of the inheritance.

INTRODUCTION

During the years 1964 to 1971 a group of twins and a control group of singletons in the same classes, were studied from grade 3 to grade 9 in the Swedish compulsory school. This study was called the SLU-project (Skolöverstyrelsens och Lärarhögskolans Utvecklingsstudie), and the aim was to study physical and mental growth during puberty. The project, initiated by Professor Yngve Norinder, has been financed by the National Board of Education and the Swedish Council for Research in the Humanities and Social Sciences.

In the SLU-project two main lines of study have been followed:

- A study of physical growth and its relationship to mental development (Lindgren, 1979).
- A study of heredity-environment influences on growth and development during adolescence. For this purpose the twin material has been used and this constitutes the content of this report.

Originally 323 twin pairs and 1194 controls were included in the SLU-sample. Several kinds of information have been collected and a description is presented below:

- Physical measurements (height and weight measurements, menarche, ratings of secondary sex characteristics).
- Ability and achievement measures (intelligence tests, standardized achievement tests).
- Self ratings.
- Ratings by teachers and classmates.
- Socioeconomic background data (father's occupation and income).

The results reported so far for the twins have mainly been concentrated upon the first two kinds of variables, physical and cognitive measurements. The reason for this has been that ratings for twins, tend to be inflated by the greater apparent similarity for monozygotic (MZ) twin pairs in comparison to dizygotic (DZ).

This report is mainly a summary and a discussion of papers presenting the twin results from the SLU-project:

I A comparison of growth in twins and singleton controls of matched age followed longitudinally from 10 to 18 years (Ljung, Fischbein & Lindgren, 1977).

II Onset of puberty in MZ and DZ twins (Fischbein, 1977 b).

III Physical capacity in twins (Engström & Fischbein, 1977).

IV Intra-pair similarity in physical growth of monozygotic and dizygotic twins during puberty (Fischbein, 1977 c).

V Profile comparisons of physical growth for monozygotic and dizygotic twin pairs (Fischbein & Nordqvist, 1978).

VI Heredity-environment interaction in the development of twins (Fischbein, 1978 a).

VII School Achievement and Test Results for Twins and Singletons in Relation to Social Background (Fischbein, 1978 b).

VIII IQ and Social Class (Fischbein, 1978 c).

IX Intra-pair similarity in IQ of monozygotic and dizygotic male twins at 12 and 18 years of age (Fischbein, 1978 d).

X Biosocial aspects on Mathematics learning (Fischbein, 1978 e).

In the following text references will be made to the above-mentioned numbers I - X.

In addition to these papers three Swedish reports presenting results from the twin study have been published (Fischbein & Lindgren, 1975; Fischbein, 1976; Fischbein, 1977 a) and occasionally references will also be made to these reports, although they are not included in this publication.

The content has been divided into six main parts:

- Comparison of the twin group and the controls in physical and cognitive development (Fischbein & Lindgren, 1975; Fischbein, 1976; I; VII).

- Methodological problems in studying genetic and environmental influences in human development.

- Discussion of heredity-environment interaction and correlation in the development of twins (Fischbein, 1977 a; II; V; VI).

- Application of twin data from the SLU-study to a model of nature-nurture contribution (Fischbein, 1977 a; III; IV; VI; IX).

- Discussion of the relative role of genetic factors in different environments (VIII; X).

- Some implications of the presented results for school organization and school policy.

DESCRIPTION OF TWIN GROUP

Comparisons of the twin group with their controls for physical growth and for different ability and achievement measures collected in the SLU-project have been made in several reports and papers (Fischbein & Lindgren, 1975; Fischbein, 1976; I; VII). Before making any attempt to estimate the proportional contribution of genetic factors to behavioural variation on the basis of twin data it has been necessary to investigate briefly in what respects and to what extent twins may differ from a normal population of singletons.

Height and weight measurements were collected from 10 to 18 years for the male SLU-twins and their controls and from 10 to 16 years for the girls (Fischbein & Lindgren, op.cit.). Menarcheal age was also registered for the girls (Bergsten-Brucefors, 1976).

There were very small differences between the twin boys and their controls in both height and weight. Twin girls, however, were significantly shorter and weighed less than the control girls.

On the basis of height and weight data peak height velocity (PHV) and peak weight velocity (PWV) have been estimated for each individual (Lindgren, 1975; 1976). For both boys and girls the height and weight peaks tended to be smaller for the twins in comparison to controls. A comparison has also been made of the age at which these criteria of physical maturity were reached for the twins and their controls. The twin boys tended to have their height peak a little earlier than the control boys, while the opposite was found for the girls. The twin girls also got their menarche a little later, on the average, than the controls. No significant differences were found between twins and controls as regards age at PWV.

In grade 5 three subtests from a group administered intelligence test (DBA) were given to the twins and their controls. The tests were constructed to measure verbal ability, inductive reasoning and clerical speed. The twins were found to have lower average scores than the controls on both the verbal and the inductive tests, while this difference was evident only for the boys on the clerical speed test.

In grades 3 and 6 results on standardized achievement tests, used to equalize marks in the Swedish schools (Ljung, 1965), were collected for the SLU-twins and their classmates. A comparison between the groups showed the twin girls to have lower average test scores, while the twin boys were very similar to singletons in school achievement.

In grades 3 to 7 an arithmetic test, the KUP-test, was given to the twins and controls. The pupils were to perform simple arithmetic calculations according to special rules. They were to continue for 42 minutes and every third minute they were to indicate how many items they had solved. The KUP-test is assumed to give an indication of a pupil's ability to concentrate, in addition to his ability to solve this type of arithmetic items (Lindgren, 1979). Comparisons of twins and controls for average number of correctly solved items showed the twin boys to be very similar to their controls. The twin girls, however, had lower average scores on the test than the controls in all grades (Fischbein, 1976, p. 36-37).

In summary, then, comparisons of physical growth and ability and achievement test results for twins and controls in the SLU-project generally show a larger difference for girls than for boys. Twin girls tend to be smaller and weigh less and have lower average test scores than control girls of the same age. A twin handicap has also been found by other investigators (Husén, 1959, 1960; Koch, 1966; Wittler, 1971), and has often been explained by the adverse prenatal conditions that twins tend to experience. There is no obvious explanation, however, why this deficit should be greater for girls than for boys. One reason could, however, be a higher mortality for the twin boys, thus an effect of selective survival.

A comparison of mortality rates for infants in Sweden during 1926-1967 for boys and girls shows that approximately 1 per cent more boys than girls among singletons died in infancy. For the twins, however, the corresponding proportion is a little more than 2 per cent (Official Statistics of Sweden, 1958; Medlund et al., 1977). The proportion of still-born children in 1955 was approximately 1 per cent for both boys and girls among singletons. For twins, on the other hand, this proportion was approximately 5 and 3 per cent for urban twin boys and twin girls respectively. Thus the sample of surviving twin boys seems to be a more positively selected group than that of the twin girls.

A final question to discuss in this chapter is whether twins are so different from singletons that this would make it impossible to generalize results found for twins to a population of singletons. For the SLU twin boys this seems not to be a serious problem, since they tend to be very similar to the control group. For the twin girls it should be kept in mind that there are certain average differences between twins and controls. The within-pair comparisons that will be presented in the following chapters, however, are only made for monozygotic twins in relation to dizygotic and the group comparisons made between these two categories have shown no significant differences whatsoever (Fischbein & Lindgren, 1975; Fischbein, 1976). The estimation of the relative contribution of genetic and environmental factors to different variables is also based not on a comparison of absolute level but on with-

in-pair similarity. It thus seems safe to conclude that generalizations from twins to singletons can be made from this kind of data.

METHODOLOGICAL PROBLEMS

In studying genetic and environmental influences on behaviour and development different methods have been used. For human beings this study has concentrated on individuals with more or less of the inheritance in common, for instance parents and children, siblings or twins. Sometimes the research objects have been adopted children that are unrelated and are living in the same environment as ordinary siblings. For obvious reasons monozygotic twin pairs with identical inheritance and dizygotic twins, which are not more similar genetically than ordinary siblings, have been of great interest to study in this field. The assumption made, when comparing the two twin categories, is that within-pair differences for MZ twins are due to environmental factors and for DZ to both genetic and environmental factors. This means that the more concordant MZ pairs are in comparison to DZ, the more influence is accredited genetic factors. Implicit in this assumption is thus that similarity in MZ pairs is caused solely by genetic factors while similarity in DZ is caused by both genetic and environmental factors. When genotype-environment interaction or correlation is present this assumption will not be correct (Goldberger, 1978; Kempthorne, 1978).

The additive model for interpreting twin data thus implies that an environmental change will contribute to a comparable change in all genotypes. Interactional effects, on the other hand, will lead to different reactions in genotypes exposed to the same environmental impact. The additive model has originally been borrowed from agricultural genetics, where it has been found useful. It is, however, a plausible assumption that interactional and correlational effects will play a more prominent role for human beings, who for instance can store experiences by means of a common language. If this is true the additive model has obvious shortcomings, since it confuses genetic and interactional effects in interpreting data from twins, who differentially react to and

construct their own environments. It will be necessary to define specifically what is meant by interactional and correlational effects in the following, since these concepts tend to have quite different meanings depending on the preferred model of explanation.

Genotype-environment interaction

Genotype-environment interaction can be estimated within the frame of an additive model of assessing the proportional contribution of genetic and environmental variance to human behavioural traits (Eaves, Last, Martin & Jinks, 1977). The proponents of this type of G x E interaction state that "genes can control sensitivity to the environment and that the environment can modulate the expression of genes" (op.cit., p. 17). The interaction term referred to above is estimated for groups of individuals in an analysis of variance design and implies that individuals high in a trait will react differently from individuals low in a trait. It is thus connected to genotypic level which presupposes a quantification of genetic contribution.

Plomin, DeFries & Loehlin (1977) have discussed the difference between the above-mentioned population concept and the organismic type of interaction. The latter connotes something more than the statistical type of interaction, namely that "the organism actively interacts with its environment" (op.cit., p. 310). The authors suggest that this should be characterized as active genotype-environment correlation instead of interaction.

Buss (1977) has stressed the importance of separating different kinds of interaction. He is not specifically discussing genotype-environment interaction but more generally what he calls person-environment interaction. In the person (P) is of course embedded genetic aspects, since P is a function of both genetic (G) and environmental (E) influences. G x E = P will determine the reaction towards E which in turn will influence G x E = P. In other words, there is a reciprocal relationship between environmental and person characteristics, the latter consisting of genotype combined

with earlier environmental influences specific for the individual. Buss refers to Overton & Reese (1973), who have developed the argument that the statistical type of interaction calculated in an analysis of variance design is linked to a mechanistic model of reasoning. The other type of interaction, on the other hand, where there is a reciprocal relationship between individual and environment, has been connected with an organismic model. Overton & Reese have argued that the two types of interaction are incompatible with each other since they are embedded in two different metaphysical systems. Buss points out that the basic difference between the mechanistic type of interaction and the organismic type is that the former predicts a nonreciprocal relationship between environmental (E) and person (P) characteristics, so that behaviour is a joint function of E x P. The organismic type of interaction, on the other hand, presupposes a reciprocal relationship and focuses upon the psychological environment and the person as these affect and are affected by each other. This is an active process, so that individuals are affected by the environment, but also react to and change environmental conditions in which they are living. This definition of interaction could also be compared to Piaget's notion of this concept (Furth, 1973). As can be seen this way of describing interaction is also very similar to the genotype-environment correlation concept described by Plomin et al. (1977).

Lerner (1978) is also discussing the reciprocal character of organism-environment relations. He proposes as well that the linear type of interactions so far favoured in nature-nurture research should be supplemented by a dynamic interactionism. "While this paradigm", he asserts, "leads to a theoretical view of development which necessarily takes a stance on the core nature-nurture issue, it does so in a manner which is capable of integrating not only the 'main effects' of nature and nurture variables, and the 'weak' or 'mechanistic' interactions among these variables, but in addition, is capable of integrating the entire range and types of potential interrelations among such variables." (op.cit., p. 3-4). Earlier twin studies have mainly concentrated on the main effects and mechanistic interactions referred to above and a consideration of dynamic interactionism will require among other things a developmental approach (Husén, 1978).

Genotype-environment correlation

Plomin et al. (1977 p. 310) distinguish three main kinds of G x E correlation and define this concept as "a function of the frequency with which certain genotypes and certain environments occur together". They point out that G x E correlation may be both positive and negative.

Passive G x E correlation is present when endowment and environment covary so that for instance bright children tend to live in a home conducive to their intellectual development. This type of correlation is called "passive" because it occurs independently of the activities of the individual in question. Of course the existence of this type of correlation does not exclude the active type of G x E correlation (see below).

Reactive G x E correlation signifies that people can react differently to persons of different genotypes, thus creating conspicuously dissimilar environmental circumstances. An example of this type of correlation is when certain personality traits are reinforced by persons in the environment. The reactive G x E correlation has often been discussed in connection with twin studies. It has been maintained that monozygotic twins tend to be treated more alike than dizygotic twins, which would make it unwarranted to assume that environments are the same for both MZ and DZ.

Active G x E correlation occurs as a result of the individual's own action. People tend to create for themselves different environments related to their genetic potentials. For instance, in the same home a brighter child may choose to read more books than a less bright child thereby creating for himself a more stimulating environment. In twin studies a few attempts have been made to separate the reactive and active type of correlation by studying wrongly classified MZ and DZ twins (Lytton, 1977; Cohen, Dibble & Grawe, 1977). It seems as though behaviour is connected to actual genotype and not perception of zygosity, since DZ misclassified as MZ also tend to be more alike genetically than DZ who are not mistaken for MZ. Parents also tend to perceive MZ twins as more similar than DZ, but they do not receive distinctly different parenting. Parental knowledge of zygosity does not,

thus, affect the way the parents treated their children. It consequently seems as though the active type of G x E correlation is a more powerful determinant of behaviour in these studies than reactive correlational effects.

Both Plomin et al. (1977) and Eaves et al. (1977) who have discussed the active type of G x E correlation, have stressed the difficulty to distinguish between this type of correlation and G x E interaction. This is purely a matter of definition, and it will probably be impossible to maintain a clearcut distinction between these two concepts.

The following definition of G x E interaction has been proposed by among others Erlenmeyer-Kimling (1972, p. 187): "What we usually mean by interaction is that genotypes can be shown to react in different ways to the same environmental treatments." This definition implies an active reaction from the individual, thus a reciprocal relationship as defined by Buss (1977). A nonreciprocal relationship would be expressed as "the same environment will affect individuals differently depending on their genotypes".

The reciprocal definition that will be used in the following will make the distinction between G x E interaction and active G x E correlation quite arbitrary. The "same" environment (e.g. living in the same home or attending the same class) will tend to affect MZ twins similarly on the basis of their identical inheritance. MZ twins will also tend to react more similarly than DZ twins to the "same" environment, thus creating more similar environments than DZ, even if they objectively are experiencing the "same" environment. The extent of interactional and correlational effects described above will tend to vary both with situational factors and with the characteristic studied. A further elaboration of these assumptions will be made in the following when a model for interpreting longitudinal twin data will be presented.

HEREDITY-ENVIRONMENT INTERACTION AND CORRELATION IN THE DEVELOPMENT OF TWINS

Species-specific development is obviously strongly genetically regulated in both man and animal. Even quite drastic environmental influences will probably not permanently change a normal growth curve. A severe illness in children can, for instance, arrest growth, but after recovery a catch up effect will normally be evident. Human beings tend to crawl before they walk, babble before they talk and the maturational cycle occurs in a certain temporal sequence (Ljung, 1965). The onset of puberty, for instance, tends to be more concordant for monozygotic twins with identical inheritance than for dizygotic twins (II; V). This is true whether the criteria used to estimate this temporal event are peak height velocity, menarche or ratings of secondary sex characteristics. Intra-class correl tions (Ljung, 1966) for age at PHV, which give a measure of within-pair similarity for timing of the height spurt, are as high as .85 for MZ boys and .78 for MZ girls. For the DZ pairs the corresponding correlations are .42 and .39.

There is, however, a large variation in human behaviour in spite of the regularity with which it appears. A study of the variation in age at PHV, for example, reveals a difference of approximately seven years between the earliest and the latest maturers (Lindgren, 1978, p. 254). Genetic and environmental influences and their interaction and correlation will tend to vary depending on characteristic studied and environmental circumstances. As shown (Fischbein, 1977 a; VI) longitudinal twin data present certain possibilities to investigate and discuss such influences. Before attempting to outline a model for heredity-environment contribution, however, some theoretical arguments will be reviewed, that have had great impact on the construction of the model. Evidently a common theme in these arguments is the developmental aspect on behavioural variation.

Waddington (1975, p. 258) explicitly assures that "we should think not in terms of homeostasis, but rather of homeorhesis, the stabilization not of a stationary state, but of a pathway of change in time". Behavioural development is pictured as an "epigenetic

landscape", where "the development of the phenotype of an individual proceeds along a valley bottom; variations of genotype, or of epigenetic environment, may push the course of development away from the valley floor, up the neighbouring hillside, but there will be a tendency for the process to find its way back, not to the point from which it was displaced - the homeostatic equilibrium - but to some later position on the canalized pathway of change, from which it was diverted".

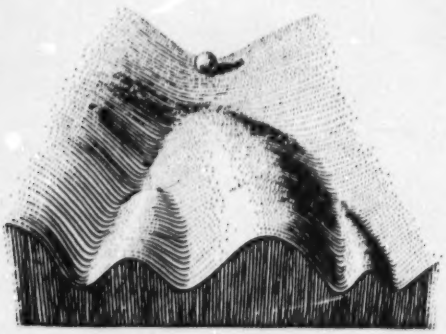


Figure 1. The epigenetic landscape (from Waddington, 1975, p. 259)

Figure 1 gives a simplified illustration of the canalization of the phenotype. The valley is the genetically regulated course of development and the ball is the phenotypic behaviour of the individual. For some characteristics, physical growth and maturity for instance, the hillsides of the valley are steep and high and it will take very drastic environmental influences to push the ball up the hillsides. For other characteristics the hillsides will be more sloping and shallow and it will take much less environmental pressure to influence the position of the ball during the course of development. There will of course be variations in the "epigenetic landscape" depending on genotype, and the reaction to environmental influences will also differ according to individual variations, which implies both genotype-environment interaction and correlation.

Fuller & Thompson (1961) have also stressed the developmental aspects on genetic and environmental influences. "The important thing is not to stop development in order to obtain pure measures of genetic effects, but to identify the factors which produce differentiation in development." (op.cit., p. 111). They outline possible outcomes of practice effects on the relative contributions of genetic and environmental factors during a time period. The "convergence" hypothesis predicts that "when one specific response is reinforced, other responses will be extinguished, and all subjects will converge upon a common pattern" (op.cit., p. 91-92). This will in the long run contribute to a reduction of genetic variance. The "divergence" hypothesis, on the other hand, predicts that "subjects free to exploit their environment in a variety of fashions will by chance light upon quite different modes of adaptation". Thus there will be an increase of the relative contribution of genetic factors to behavioural variation.

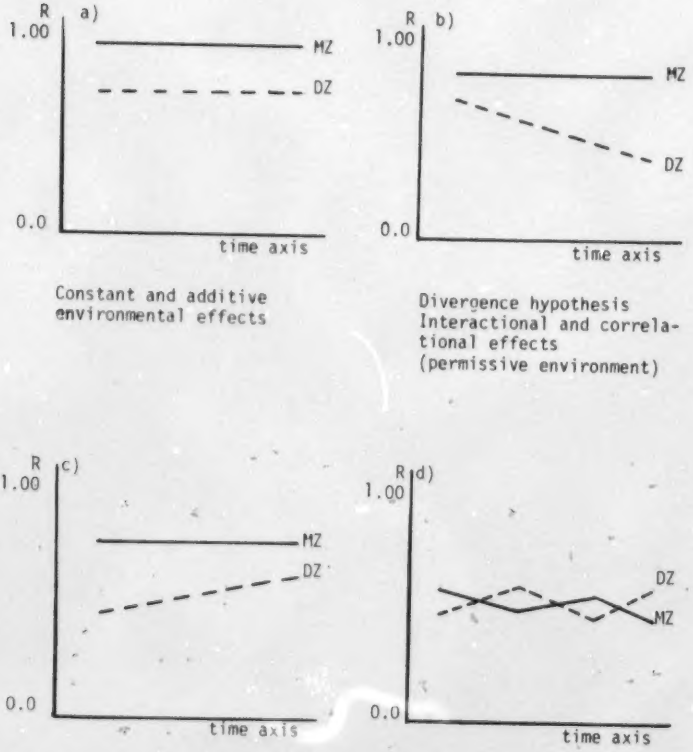
The convergence and divergence hypotheses thus imply a difference in genetic contribution to a variable depending upon the amount of freedom given the phenotype to interact with environmental factors. In a restricted environment genetic factors will contribute less to variation than in a permissive and stimulating environment.

The theoretical contributions by Waddington and Fuller & Thompson presented above have certain implications for the construction of a model of nature-nurture contribution studied on longitudinal twin data. Waddington stresses variations depending upon the characteristic studied, while Fuller & Thompson are more concerned about variations in environmental circumstances.

Model of nature-nurture contribution

A model for interpreting longitudinal twin data would thus require both that interactional and correlational aspects are taken into account and an adaptiveness to type of characteristic studied and environmental factors relevant for the development of this characteristic.

Figure 2 is an attempt to outline such a model. Hypothetical intra-pair correlations are given for MZ and DZ twin pairs under the assumption that the twins in a pair are living in the "same" environment, and are exposed to the "same" environmental impact.



Constant and additive environmental effects

Divergence hypothesis Interactional and correlational effects (permissive environment)

Convergence hypothesis (restricted environment)

A variable primarily controlled by environmental factors

Figure 2. Hypothetical intra-class correlations for MZ and DZ twins assuming "same" environments, and varying nature-nurture contribution

Example a) illustrates development of a characteristic primarily controlled by genetic factors, where environmental effects are assumed to be constant and additive. MZ twins, due to their identical inheritance, tend to be more similar than DZ twins and this difference tends to be of the same magnitude as long as the twins are exposed to the same environmental impact. No lowering of the intra-pair correlations with increasing age is hypothesized.

Example b) illustrates the divergence hypothesis proposed by Fuller & Thompson (1961). Under permissive circumstances MZ twins react similarly to the same environmental influences, while DZ twins react differently and thus get progressively less similar. A lowering of the intra-pair correlations for DZ twins but not for MZ with increasing age is hypothesized.

Example c) illustrates the convergence hypothesis also suggested by Fuller & Thompson. Due to restricted environmental influences negatively reinforcing genetic differences DZ twins will get progressively more similar with increasing age. The intra-pair correlations for DZ will thus be higher with increasing age and remain constant for MZ twins.

Example d) illustrates unsystematic environmental effects largely counteracting genetic differences. Since the identical inheritance of MZ twins does not predispose them for greater similarity, it will be rather incidental if the intra-pair correlations for MZ will be higher or lower than for DZ.

Of course this model is not static, but the results will vary with the population studied and cultural environment involved. What is classified in one society as a characteristic under a) might for instance be susceptible to interactional and correlational effects as in example b) in different environmental circumstances. Assuming comparable (similar degree of genetic regulation) variables,

constitutional factors will be of relatively minor importance in a restrictive environment and greater importance in a permissive environment.

APPLICATION OF TWIN DATA TO MODEL

In this chapter the longitudinal twin data, collected in the SLU-project, will be discussed with reference to the model of nature-nurture contribution, presented in the preceding chapter. Each of the SLU twin pairs is living in the same home and generally they attend the same classes at school. It could thus be maintained that the twins to a large extent are exposed to similar environmental influences.

Physical growth

Height growth can be assumed to be a largely genetically regulated variable, at least when adequate nutritional supply is provided. Weight growth, on the other hand, is clearly much more environmentally influenced and regulated through food intake and physical activity. Different hypothetical outcomes for within-pair similarity in height and weight growth during puberty for MZ and DZ twins could therefore be predicted on the basis of the model presented earlier:

- For height growth a parallel trend in accordance with example a) would be expected so that MZ twin pairs tend to be more similar than DZ twin pairs during puberty. No lowering of the intra-pair correlations with increasing age is hypothesized.
- For weight growth a divergent trend according to example b) is expected since in the surplus situation prevailing in our society, the twins will be free to choose both food intake and exercise. A lowering of the intra-pair correlations for DZ twins but not for MZ with increasing age is hypothesized.

Intra-class correlations (Ljung, 1966) for height from 10 to 18 years of age are presented in figure 3 for MZ and DZ boys and from 10 to 16 years for MZ and DZ girls (IV).

16

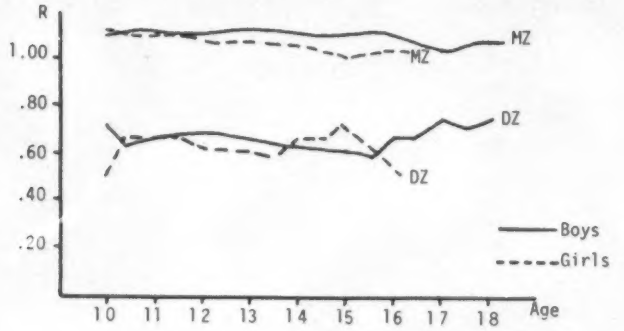


Figure 3. Intra-class correlations of twin girls and twin boys for height.

As can be seen from this figure MZ pairs are very similar to each other in height during puberty. The correlation is around .90 for both boys and girls. The correlations for the DZ pairs typically are around .60-.70.

The correlations for weight show a different trend as can be seen in figure 4.

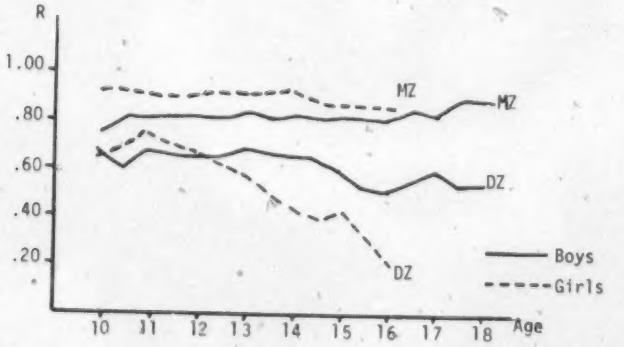


Figure 4. Intra-class correlations of twin girls and twin boys for weight.

The correlations for the MZ pairs tend to be high for weight also, around .80-.90. For the DZ pairs, however, there seem to be a divergent trend so that the twins are more similar for weight at age 10 than at age 16 or 18. This is especially evident for girls, where the intra-class correlation decreases to around .20 at age 16.

It can thus be seen that the intra-class correlations for height largely follow the pattern illustrated in example a) in the model, while the pattern for weight is much more similar to example b). Height growth tends to be primarily controlled by genetic factors. Weight growth, on the other hand, is much more susceptible to interactional and correlational influences. Weight is of course a variable that is much more individually regulated than height and possibly equal consumption will give different effects depending upon variations in metabolism. Furthermore, if an individual is beginning to get overweight, he will be able to do something about it, maybe eat less or another type of food, or exercise more. This regulation is, also, linked to hereditary factors so that persons with different inheritance will react differently to the same environmental influences (e.g. food intake or exercise). The same offerings of food in a home will thus tend to affect the twins in a pair differently if they are dizygotic, but similarly if they are monozygotic. The within-pair similarity in MZ twins consequently includes environmental (interactional and correlational) components. From this example it can also be seen that it is very complicated to separate the two effects from each other. If identical nutrition affects the DZ twins differently then it is an interactional effect, but if the twins react differently to the nutritional supply and choose different things they will themselves create divergent environments and the effect would be classified as correlational.

The sex difference found for weight growth during puberty thus has a plausible explanation, since girls in this age presumably are much more concerned about their weight and regulate it more than boys. This could also be connected with the more rapid change in girls at puberty compared to boys (Lindgren, 1979). A larger amount of physical activity practiced by the boys may also contri-

bute to a decrease in the weight fluctuation during this period (Engström, 1975). It is also a plausible hypothesis that the weight regulation is much more automatic and physically controlled under heavy physical training (Astrand & Rodahl, 1970).

Ability and achievement test results

Verbal and inductive ability test results have been collected for the boys in grade 5 at age 12 and again at the enrollment to military service at age 18. Standardized achievement test scores in Mathematics were registered for both boys and girls in grades 3 and 6. In addition to this the KUP-test (p. 4) was given every year from grades 3 to 7 in order to study if the children's ability to concentrate on a specific task for a limited time period fluctuated during puberty. A description of within-pair similarity for the twins on this test has been given by Fischbein (1977 a).

On the basis of the model presented earlier hypothetical outcomes of changes over time in within-pair similarity for MZ and DZ twins can be predicted for the different types of test results. Verbal ability can, for instance, be expected to be more environmentally influenced than inductive ability and it is also conceivable that interactional and correlational effects will be more prominent for verbal than for inductive ability (IX):

- For verbal ability a divergent trend would thus be expected so that a lowering of the intra-class correlation for DZ but not for MZ twins with increasing age is hypothesized.
- For inductive reasoning ability a parallel trend is expected so that the difference between intra-class correlations for MZ and DZ twins are predicted to be of the same magnitude both at age 12 and 18.

In figure 5 the intra-class correlations for the verbal and inductive tests at age 12 and 18 are presented for MZ and DZ twin boys. At age 18 only pairs with equal length of schooling have been included, since this factor may influence test results. The actual correlation coefficients and the number of pairs are given by Fischbein (IX).

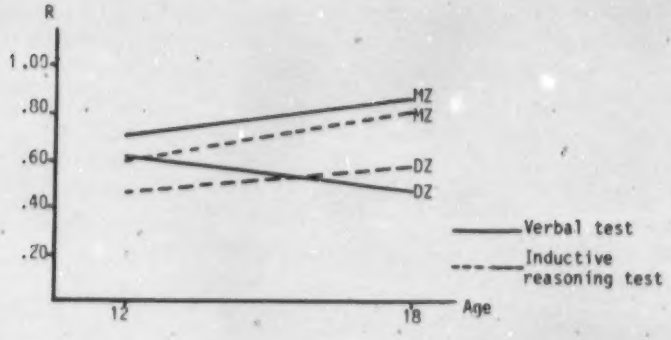


Figure 5. Intra-class correlations for verbal and inductive reasoning ability at age 12 and 18 for male MZ and DZ twins with the same length of schooling.

A comparison of the intra-class correlations for verbal ability shows an increase from around .70 to .85 for MZ twins from 12 to 18 years of age, and a decrease from around .60 to .50 for DZ twins. The gap between the twin categories as regards within-pair similarity thus tends to grow from 12 to 18 years.

The correlations for the inductive tests tend to increase for both MZ and DZ twins from 12 to 18 years of age (from around .60 to .80 for MZ pairs and from around .45 to .55 for DZ). The increase is approximately of the same magnitude, however, for both MZ and DZ twins.

The divergent hypothesis thus seems to be applicable to the results for verbal ability. This would seem to imply that interactional and correlational effects are of considerable importance for explaining the variation in test scores. The verbal training received both at home and at school tends to have a differential effect for the DZ twins and a similar impact on MZ twins in a pair. On the basis of their different inheritance the DZ pairs thus seem to be affected and react differently to similar environmental influences, while the identical twins are affected and react in a similar way to this influence.

Inductive test results do not show the divergent trend described above. The correlations tend to increase for both MZ and DZ twins from age 12 to age 18. There is neither a divergent nor a convergent trend and the difference between the intra-class correlations tends to be only slightly larger at age 18. These results seem to imply that the variation in inductive ability is less susceptible to heredity-environment interaction and correlation. This explanation is of course tenable only under the circumstances given in the SLU-study. The kind of ability measured by the inductive tests is probably much less influenced by parental or school activities than the verbal tests. If, however, a training of the inductive type of test items was induced, this would possibly affect the results achieved. The rise in intra-class correlations for both MZ and DZ twin pairs between age 12 and 18, may be explained by a growth in the capacity to solve items measuring abstract logical reasoning. At 12 years of age this kind of test is very difficult for many late maturers and this may lead to more unexplained and unsystematic variance. The possibility must of course also be taken into account that the tests used on the two separate occasions are not quite comparable, and that this could contribute to the observed rise of the intra-class correlations.

Achievement test results in Mathematics have been studied longitudinally in grades 3 and 6 in the SLU-project. These tests, used in the Swedish school system to equalize marks, are constructed to measure advances made according to the curriculum (Ljung, 1965, p. 57 ff). They can thus be said mainly to check the effects of training. The hypothesis made in reference to the model on page 14 would be that the more regulated and restricted the content the more concordant the trends would be for the two twin categories. On the other hand, if there is a free and permissive educational environment a discordant trend would be predicted. Of course this will also depend on the type of achievement studied. For certain kinds of motor activities, e.g. arm strength or vital capacity, interactional and correlational effects will have much less significance than for the types of cognitive variables discussed here (III).

The construction of the standardized achievement tests and the curriculum content in Swedish schools would lead to the assumption

that for these types of test results interactional and correlational factors will be of great importance. Lundgren (1977) has for instance hypothesized that "differences between children will increase cumulatively as a result of the teaching process" (p. 227). This could also be suspected for the reason that it has been a trend in Swedish schools towards a reduced societal pressure and use of varying control instruments. The differentiation of development with increasing age is, of course, well documented and will also lead to a formulation of the following hypothesis (Ljung, 1965, p. 130-131):

. For standardized achievement test results in Mathematics a divergent trend would thus be expected so that a lowering of the intra-class correlation for DZ but not for MZ twins with increasing age is hypothesized.

Figure 6 gives the intra-class correlations for the Mathematics test in grades 3 and 6 for MZ and DZ twin girls and twin boys. A thorough presentation of the results and the number of pairs on which they are based is given by Fischbein (X). In order to make educational environment as similar as possible for the twins in a pair, only pairs attending the same classes in grades 3 and 6 have been included. In spite of this we can see that the DZ twin pairs tend to be less concordant for achievement test results in grade 6 than in grade 3. The opposite is true for MZ pairs and this trend is the same for both boys and girls.

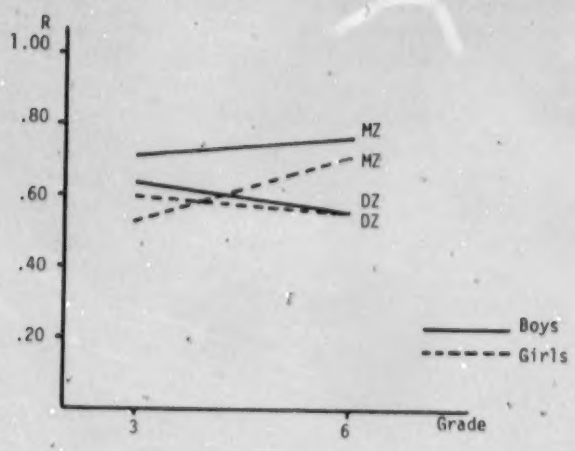


Figure 6. Intra-class correlations in Mathematics for twin boys and twin girls in grades 3 and 6.

Obviously a similar training does not make children more similar in the variable trained, not even if they are dizygotic twins living in the same homes. MZ twins, however, do tend to get more concordant, since they are affected and react similarly to the type of environmental influences provided by the school.

The KUP-test is a combination of both arithmetic achievement, which is trained at school, and ability to concentrate on a specific task for a given time period, while using specific rules introduced in the instruction to the test. Both Brucefors (1973) and Lindgren (1978) have shown that there is a moderate positive correlation between the KUP-test and the verbal and inductive DBA-tests (.35-.50). It also shows a correlation of approximately the same magnitude with marks and achievement test results in Swedish and Mathematics. It thus seems as though, in addition to arithmetic achievement and ability to concentrate, a common factor generally found for numerical operations tests also is an important component in the KUP-test (Lindgren, op.cit., p. 8). It is very difficult to hypothesize a specific trend for the KUP-test results, since the test is a mixture of genetically induced abi-

lity but also very susceptible to environmental disturbances. Within-pair similarity probably will fluctuate from one grade to another depending upon classroom climate, even if MZ twins will tend generally to be more concordant than DZ on account of their greater genetic similarity.

In figure 7 intra-pair similarity for MZ and DZ twins on the KUP-test is presented. As for achievement test results only twin pairs attending the same classes have been included in the analysis. Average within-pair differences for the twins have been given by Fischbein (1977 a, p. 82-89).

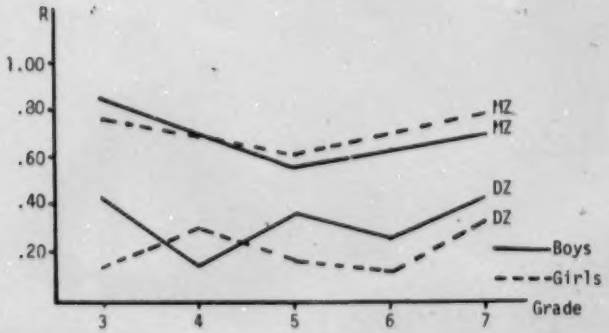


Figure 7. Intra-class correlations for KUP-test results in grades 3 - 7 for MZ and DZ twin girls and twin boys

Figure 7 illustrates the intra-class correlations in grades 3-7 for twin boys and twin girls (Fischbein, op.cit.). Perhaps the most striking result is the fluctuation of correlations for both MZ and DZ twins, although MZ twins tend to be more similar than DZ in every grade. There is no consistent discordant or concordant trend and this could also not be expected, since the children have not been specifically trained to solve the types of items included in the test. A possible explanation to the large fluctuation from one grade to another might be the above-mentioned sensitivity of the test to external influences. For instance, if there are some disturbing elements in the classroom situation, it will

be very difficult to concentrate on this type of test. A comparison of results for boys and girls leads to the assumption that boys tend to be more influenced by such external influences than girls, since the fluctuations tend to be somewhat larger for the boys.

In summary then, heredity-environment interaction and correlation seem to contribute most to variation for weight growth and verbal ability as well as for Mathematics achievement at school. Height growth and inductive ability tend to be primarily genetically regulated under the circumstances present in the SLU-project, where the nutritional supply and environmental stimulation for most children can be considered sufficient. The KUP-test seems to be rather sensitive to unsystematic external influences in the classroom situation. If this test was systematically used at school for evaluative purposes, and a training of the ability to solve these types of items would take place the intra-class correlations for the twin categories would probably fluctuate much less from one grade to another.

THE RELATIVE ROLE PLAYED BY GENETIC FACTORS IN DIFFERENT SOCIAL GROUPS

Heredity-environment contributions discussed so far have been concerned with behavioural development and variation at the individual level. In other words, latent causes influencing individual growth have been the topic of investigation. This chapter will focus more on heredity-environment contribution to group differences found in the SLU-material.

Perhaps the most violently debated group differences have been the differences in intelligence test scores usually found between social classes in human societies. Jensen (1969) and others have maintained that such differences are primarily innate and genetically regulated. This has led to a pessimistic view on the possibilities of decreasing these differences by means of compensating programs for children from the lower social classes (VIII).

Jensen has mainly referred to results from twin studies when presenting his arguments. In doing so he has not taken into consideration the organismic or dynamic type of heredity-environment interaction and correlation, the effects of which can be quite substantial as has been shown in this report. Of course Jensen has discussed concepts of interaction and correlation in detail and tried to estimate their effects in one of his books (Jensen, 1972, p. 110-114). This has only been done, however, in an analysis of variance design, where the greater similarity of MZ twins in comparison to DZ is considered to be a genetic main effect. Mechanistic interaction effects are estimated to contribute about 15 % to the variation in test scores. Jensen bases his conclusions solely on cross-sectional twin data and, as has been shown, longitudinal data give larger possibilities to study different types of heredity-environment interaction and correlation. The probability that such effects would be of more or less significance in different cultural surroundings has not been much discussed by Jensen and his followers. Yet we have seen that environmental circumstances tend to be of great importance when interpreting results from twin studies (p. 14). Scarr-Salapatek (1971) has compared within-pair similarity in IQ for black and white twins from different social classes and she also found varying outcomes in different cultural surroundings. She concluded that a more stimulating environment for the development of the abilities measured by traditional intelligence tests would lead to a larger discrepancy in within-pair differences for MZ and DZ twins. For disadvantaged groups, such as black children from lower social classes, environmental factors would thus contribute relatively more to the variation in such test scores.

Social group differences in the SLU-material are found mainly for the verbal and inductive ability tests in grade 5 and for standardized achievement test results in grades 3 and 6 (VII). It would therefore be of interest to study nature-nurture contribution to the variation in those test results for different social groups.

Mental ability test results

The conclusions drawn by Scarr-Salapatek (1971) would lead to the hypothesis that intra-class correlations for mental ability test results should be of approximately the same magnitude for MZ and DZ twins in social group III, while the discrepancy between the twin categories should be substantial in social group I, where the environmental stimulation of such abilities can be expected to be higher. A description of the socioeconomic classification used in the SLU-study has been given by Lindgren (1976).

A testing of the above-mentioned hypothesis has been made by Fischbein (VIII) and, the analysis of variance results for the verbal and inductive tests are given in table 1, where within- and between-pair variance as well as intra-class correlations for MZ and DZ twins in social group I, II and III are presented. Unfortunately it has not been possible to make a longitudinal analysis of the mental ability test results, since only boys have been tested at age 18 and a grouping for social background at this age is impossible due to the small number of pairs.

Table 1. Analysis of variance of verbal and inductive scores of twin pairs by social group

	Social group I		Social group II		Social group III	
	MZ	DZ	MZ	DZ	MZ	DZ
			Verbal test			
N	16	22	43	44	31	58
V_{bp}	5.33	4.18	6.12	4.89	4.13	4.72
V_{wp}	1.06	1.68	1.34	1.85	0.90	1.52
F	5.01	2.48	4.58	2.64	4.57	3.11
R	0.667	0.426	0.641	0.450	0.641	0.513
			Inductive test			
N	16	22	43	44	31	58
V_{bp}	4.90	4.40	6.38	5.57	3.22	5.65
V_{wp}	1.38	2.57	1.59	2.44	1.39	3.19
F	3.56	1.72	4.00	2.28	2.32	1.77
R	0.562	0.263	0.600	0.390	0.398	0.278

For the verbal test the within-pair variance (V_{wp}) for both MZ and DZ twins seems to be smaller in social group III compared to groups I and II. For the inductive test, on the other hand, the within-pair variance for MZ twins is about the same in all social groups, while for DZ it is somewhat larger in group III, which means that DZ twins tend to be less similar for inductive test results in group III compared to group I and II. The intra-class correlation coefficients are also conspicuously low for the inductive test in social group III. Possibly these low correlations reflect random, unsystematic environmental effects. The abstract logical reasoning ability supposedly measured by the inductive test can be assumed to be unsufficiently developed at this age. A comparison of intra-class correlations for inductive tests at age 12 and 18 also show substantially lower correlations at age 12 (IX).

For both the verbal and the inductive tests MZ twins tend to show considerably higher within-pair correlations in comparison to DZ twins in social groups I and II (around .50-.60 for MZ and .30-.40 for DZ). In social group III, however, the correlations for MZ and DZ tend to be of the same magnitude (around .60 and .50 respectively for the verbal test and .40 and .30 for the inductive test). This seems to imply that genetic variance (including interactional and correlational effects) accounts for a larger part of the variation in mental ability test scores in social group I and II compared to social group III.

The hypothesis presented above predicted that a larger part of the variation in test scores could be explained by environmental influences in social group III compared to social group I or II. This would reflect itself in a smaller discrepancy between MZ and DZ correlations in group III and a larger in group I. As can be seen from table 1 this hypothetic outcome is verified for both the verbal and the inductive tests. The gap between the intraclass correlations for MZ and DZ pairs tends to decrease in social group III compared to group I or II. The more concordant MZ twins are in comparison to DZ, the more influential genetic factors can be estimated to be and consequently, the smaller the discrepancy between MZ and DZ correlations the greater importance can be accorded to environmentally induced influences, such as lack of stimulation or unfamiliarity with test-taking procedures. Of course the genetic variance mentioned above will include both interactional and correlational effects discussed earlier, since they tend to be controlled by individual endowments. It will, however, be impossible to estimate the importance of such effects for the different social groups due to lack of longitudinal ability test results for both sexes.

Standardized achievement test results

Similarity in achievement test results for MZ and DZ twin pairs with varying social background is of special interest to study for two main reasons. Firstly, it will be possible to study the effect of training at school on the within-pair similarity and secondly, to study heredity-environment interaction and correla-

tion in different social groups by means of longitudinal achievement test results in Mathematics.

It could be hypothesized that training at school of the skills measured by achievement test items would counteract the results found for the mental ability tests, since all children will be exposed to a stimulation of the abilities measured by the test. This training could, however, also be suspected to have differential effects for children with varying socioeconomic backgrounds, since the content of instruction at school tends to be more or less suitable to the previous experiences of different children (Lundgren, 1977).

Table 2 illustrates within- and between-pair variance as well as the intra-class correlations for the achievement test in Swedish in grade 3 for MZ and DZ twin pairs from different social groups. Due to a very small number of pairs in social group I, the analysis has been made for group I + II together and group III separately.

Table 2. Analysis of variance of achievement test results in Swedish for MZ and DZ twin pairs by social group

	Social group I + II		Social group III	
	MZ	DZ	MZ	DZ
N	29	44	18	21
V_{bp}	93.12	92.81	72.72	87.23
V_{wp}	12.74	13.21	9.64	26.81
F	7.31	7.03	7.54	3.25
R	.76	.75	.77	.53

It can be seen from table 2 that the results for MZ and DZ pairs in group I + II are very similar, while in group III the MZ pairs seem to be much more concordant for test results than DZ pairs. This is reflected in the intra-class correlations, which are prac-

tically identical for MZ and DZ in group I + II (.76 and .75) but considerably different in group III (.77 and .53).

Within-pair similarity for the Mathematics test in grades 3 and 6 is shown in figure 8 for social groups I + II and III. A presentation of the analysis of variance results and a more thorough discussion of these results has been given by Fischbein (X).

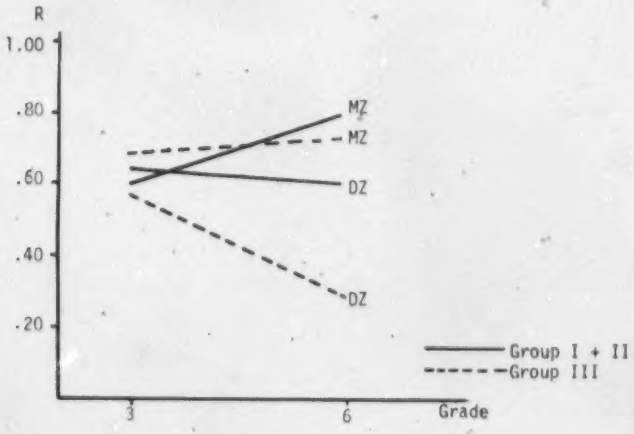


Figure 8. Intra-class correlations for Mathematics in grades 3 and 6 for MZ and DZ twins from different social groups.

For MZ twins in group I + II within-pair similarity in Mathematics results increases from grade 3 to grade 6. For DZ pairs the difference between grade 3 and 6 is negligible. In group III, on the other hand, there is a drastic change from grade 3 to 6 for the DZ pairs since the intra-class correlation drops from around .60 in grade 3 to around .30 in grade 6. For MZ pairs there is only a minor change in within-pair similarity from grade 3 to 6. It thus seems as though the decrease in within-pair similarity for DZ twins from grade 3 to 6, demonstrated for the total twin group (p. 23) largely can be referred to children from social group III.

The instruction given at school in Swedish and Mathematics thus seems to counteract the results received for the mental ability tests (p. 28). For these tests the discrepancy between the intra-class correlations for MZ and DZ twins tended to be largest in social group I and smallest in social group III. For the achievement test results there is a reversed tendency in grade 6 so that the difference between correlations is largest in group III and smallest in group I. This seems to imply than children with different genotypes from social group III tend to react very differently to the same kind of instruction on the basis of their endowments and earlier experiences. Children from social group I, on the other hand, tend to react much more similarly. When a similar instructional material is given to all children in school and a certain amount of freedom to choose from this material is available, there will be a larger variation in what is learned in social group III compared to social group I.

The interactional and correlational effects demonstrated for the achievement test results (p. 23) thus seem applicable for social group III but not for group I + II. Children from group I + II seem to react more similarly to instructional demands probably at least partly due to uniform parental pressure and stimulation.

In summary then, a comparison of the mental ability and achievement test results for the social groups shows opposite trends. The difference between intra-class correlations for MZ and DZ twins is largest for social group I and smallest for group III for the mental ability tests. For the achievement tests, however, this discrepancy is largest for social group III and smallest for group I + II. The explanation for this seems to be the training effect present for the achievement tests. All children, irrespective of social background, go to school and are exposed to some training. The children from social group III will thereby react more differently according to heritage to this training than children from group I + II.

Mental ability test items are not explicitly trained at school or at home but possibly children from social group I are exposed to more stimulation and hence develop to their full potentials in this field than children from group III. It can thus be assumed

that the small discrepancy between MZ and DZ correlations in group III is due primarily to lack of stimulation, which of course is an environmental effect (VIII).

GENERAL DISCUSSION AND SOME IMPLICATIONS FOR SCHOOL POLICY

It has been maintained in this report that earlier twin studies generally have neglected effects applicable to heredity-environment interaction and correlation. True enough such effects have been estimated in analysis of variance designs and have often been shown to be of minor importance. It can be suggested, however, that those estimates, based on comparisons of within-pair similarity of MZ and DZ twins, will tend to overestimate hereditary effects since these are inflated by interactional and correlational influences. By heredity-environment interaction is inferred a tendency for a similar environmental impact to affect individuals differentially and by correlation that individuals tend to react differently to environmental influences, thereby actively creating dissimilar environmental circumstances. Longitudinal twin data, such as those provided in the SLU-project, give unique possibilities to study such influences during a period when the twins are experiencing the "same" environments and are exposed to similar training influences.

A model has been presented that involves determinants of individual variation for different types of characteristics and under different environmental circumstances. Varying outcomes can be predicted according to this model:

a) MZ twin pairs are uniformly more concordant than DZ pairs during a period when they are exposed to similar environmental influences. This should be applicable to characteristics, where the variation is determined primarily by genetic factors and environmental influences are constant and additive.

b) There is a discordant trend so that within-pair similarity for MZ twins tends to be uniformly high, while DZ twins grow more discordant during similar environmental exposure. This trend can be explained by means of heredity-environment interactio-

nal and correlational effects. This assumption implies that individuals with identical inheritance will be affected and react similarly to environmental influences while individuals with non-identical inheritance will be affected and react differently and thus get more discordant over a time period, when they are exposed to similar environmental circumstances. This trend will be especially evident for characteristics, where a large amount of freedom is given to interpret environmental influences differentially.

c) A concordant trend is evident when within-pair similarity for MZ twins is uniformly high and DZ twins also tend to grow more concordant over a time period when the twins are exposed to similar environmental influences. These will have a similar effect for both MZ and DZ and interactional and correlational effects will be negligible. The concordant trend will be especially evident for certain types of characteristics and for restricted situations where only certain behaviours are allowed or encouraged.

d) There is no consistent trend either discordant or concordant and MZ twins are not uniformly more similar than DZ. If environmental factors primarily determine variation in a characteristic sometimes DZ twins will be more similar and sometimes MZ and this will be a random effect.

Looking at the variables available for the SLU-twins it can be concluded that height growth during puberty shows a trend consistent with a) above. MZ twins are uniformly more concordant for height growth from 10 to 18 years than DZ twins and there is no discordant or concordant trend. This would imply that height is a genetically regulated variable in our society with sufficient nutritional supply.

Weight growth, on the other hand, shows a discordant trend consistent with b) and this is especially evident for girls. Environmental factors (e.g. food intake or physical exercise) thus tend to influence individuals differentially depending upon their endowments and in our society girls are probably more concerned with their weight during puberty and try to regulate it more than boys.

Cognitive growth, measured by a group-administered ability test and school achievement tests, also tends to show a discordant trend, at least for verbal ability and Mathematics achievement. The trend for inductive ability is more consistent with a) above and shows neither a discordant nor a concordant trend. It can be assumed that this is due to the verbal ability and Mathematics achievement tests being more susceptible to training than the inductive ability test. It is quite understandable that interactional and correlational effects should be of great importance for verbal ability and school achievement, since the same environmental influences will tend to be experienced differently by individuals with different endowments. In a very restricted environment, where certain behaviours are reinforced and others extinguished, this would probably be much less evident.

A test measuring concentration and perseverance as well as arithmetic achievement has also been given to the SLU-twins in grades 3-7. The results show no consistent trend neither discordant nor concordant. MZ twins tend to be more similar than DZ in all grades but the magnitude of the difference between the twin categories varies. This would indicate that this type of test is very susceptible to environmental influences in the classroom.

The results so far have been discussed at the individual or micro level assuming similar environmental circumstances for all individuals. It could, however, also be hypothesized that the trends discussed here might be quite different for individuals living in different societies or within a society for groups being exposed to differential environmental conditions of importance for the characteristic studied. For instance, if there are large differences between schools in a society in the amount of freedom given to achieve the established goals, it could be hypothesized that heredity-environment interactional and correlational effects would be more conspicuous in schools with more freedom and less conspicuous in schools with less freedom. This comparison has not been possible to make in the Swedish school system, where schools tend to be quite uniform compared to other societies. There are, however, quite substantial differences between socioeconomic groups in results on the mental ability and achievement tests used in the SLU-study. It has therefore been of interest to study

within-pair similarity for MZ and DZ twins in different socioeconomic groups. The results show quite different trends for the mental ability test results in comparison to the achievement tests. For the ability tests the discrepancy in similarity between twin categories is larger in social group I and smaller in group III and for achievement test results the opposite trend is evident. This can possibly be explained by the training given in school of the abilities measured by the achievement tests. All children, irrespective of social background, are exposed to this training but children from social group III will react more differently on the basis of endowment to it if there is a large amount of freedom to do so. It could probably also be maintained that schools present a more restricted environment for children from social group I both because of a stronger parental pressure and stimulation of specific abilities and because children are not encouraged at school to learn more than the curriculum established for each grade. Verbal and inductive ability, on the other hand, can not be assumed to be uniformly stimulated in all social groups. Instead it seems as though optimal stimulation in social group I gives large interactional and correlational effects while lack of stimulation of abilities measured by the tests leads to negligible differences between twin categories in social group III.

It will be evident from the summary of results presented that nature-nurture influences tend to vary depending upon both the characteristic studied and the existing environmental conditions. A more permissive and free environment generally will lead to greater interactional and correlational effects whereas a more restricted environment will lead to more variance being explained by environmental influences experienced by individuals. The heredity-environment interaction and correlation can therefore be regulated to a certain extent by environmental changes. It is thus of great importance to discuss the probable effect of such changes. It could be of interest in this connection to examine this proposition more closely in an historical and educational context.

Educational change in an historical perspective

Johansson (1977 a) has studied the history of literacy in Sweden and discusses useful theoretical concepts relevant also in an evolutionary perspective on nature-nurture influences at the macro-level. He calls the two concepts "push"- and "pull"-patterns. The former pattern is characteristic of a general campaign at the societal level where purposeful educational measures are used to bring about an improvement in reading ability. The latter pattern characterizes the differences present between individuals from different groups within the society, depending upon the fact that the need for reading improvement will vary between individuals and groups. The "push"- and "pull"-pattern can easily be applied to the relative magnitude of nature-nurture influences discussed earlier in this report. In a "push"-situation where a large amount of pressure is used to ensure uniform achievement individual and group differences will decrease and genetic factors will contribute less to variation in the characteristic studied. In a "pull"-situation, on the other hand, where a large amount of freedom is given for individuals to choose what and how much to learn according to their needs and abilities, a large variation will result and genetic factors (e.g. interactional and correlational effects) can be assumed to contribute relatively more to this variation. These arguments can be applied to the previously presented model (p. 14). A restricted environment would be a situation where a lot of pressure is used to assure equal achievement, while a permissive environment would allow much more individual variation leading to larger interactional and correlational effects, It is of course not self-evident what should be inferred from the concepts restrictive and permissive. A restrictive educational situation could probably be accomplished in different ways, both intrinsic and extrinsic. Intrinsic restriction could be for instance a detailed structuring of the situation, while extrinsic restriction could be rewarding or controlling instruments. Looking at the Swedish educational system in a time perspective would probably lead to a conclusion that, by and large, there is a permissive trend leading to a decrease in the use of control instruments and insistance on free and permissive education for everyone.

In his historical review of the Swedish school system Lundgren (1977) has stressed the incoherence between organisational reforms and the educational content in schools. The latter has largely been left to subject specialists, while organizational reforms have been brought about by political decisions. He also states that "equalization effects, for example, have not been interpreted in relation to the content of teaching" (op.cit., p. 114).

Emanuelsson (1974) has also pointed to the contradictions inherent in the curriculum which stresses both the free individualistic approach and at the same time the controlling societal demanding approach. What is producing a change in one or the other direction is not, however, so much what is written in the curriculum but the organizational restrictions inherent in the educational system. In this sense it could probably be maintained that there has been a trend in Sweden towards less use of some of these extrinsic organizational restrictions, for instance different types of control instruments, such as central testing, marks in each grade, control of presence in school etc. Even if a formal decision to decrease the use of these instruments had not been taken when the SLU-twins were still attending compulsory school, it was anyhow a trend already in this direction. We have also seen, when discussing the twin results in this report, that there seem to be large interactional and correlational effects in school achievement at least for Mathematics, which would be expected in a permissive environment.

Referring to current Swedish school debate it could be of interest to review briefly arguments presented by Grundin (1976 and 1977) and Johansson (1977 b and c). Grundin (1975) has presented results indicating that around 15 % of pupils leaving compulsory school after grade 9 have great difficulties in reading and writing Swedish. This has induced Johansson to question if we are moving towards a new illiteracy in Sweden. He points out that history shows that the ability to read and write among the inhabitants of even a modern developed society can not be taken for granted. The conclusion must be that a certain societal pressure is necessary to guarantee basic skills. Kilborn and Johansson (1976) have presented similar evidence for a decrease in the

knowledge of Mathematics when leaving school and such results will probably also in the long run lead to demands for more societal pressure and less freedom to choose according to individual needs.

The debate presented above is of course closely linked to the kind of society in which the school is a part. Few would probably dispute the necessity of basic skills in Swedish and Mathematics in a modern technological society, but it could be maintained that there also is a need for a large variation in abilities and that not only theoretical knowledge and ability should be promoted.

Educational debate

When analysing the Swedish compulsory school system two main goals can be distinguished:

- The school should provide the "same" basic skills for everyone (Emanuelsson, op.cit., p. 44). The assumption behind this goal is that it will lead to a reduction of differences in the achievement of basic skills.
- The school should provide an education according to individual needs, abilities and interests (Emanuelsson, op.cit., p. 44). The assumption is that this will promote the optimal development of each pupil.

A pertinent question, when looking at these two goals, is whether the pupils should be adjusted to the school system or the school system should be adjusted to the needs of the pupils. It could be maintained that the former goal is inclined to fit pupils into the school organization, while the latter emphasizes the fitting of the school organization to the pupils.

Achievement of basic skills

The concept of "mastery learning" discussed by Bloom (1976) has some implications for the organization of the educational system in accordance with the achievement of basic skills. He insists that it is possible for practically all pupils to achieve the same basic skills in, for instance, Swedish and Mathematics. This goal can not be accomplished, however, by giving all pupils the same treatment (instruction). Bloom points out that if "students are normally distributed with respect to *aptitude* for some subject and all students are given exactly the *same instruction* (the same in terms of amount and quality of instruction and time allowed for learning a specific content), then completion of the subject will be normally distributed" (op.cit., p. 4). This will also lead to a high correlation between aptitude measured at the beginning and at the end of instruction. On the other hand, if each pupil receives the kind of instruction and time necessary to achieve a certain level of basic knowledge and nothing more, variation in this respect will tend to diminish and disappear at the end of instruction. Bloom also underlines the necessity to apply unequal treatment at the beginning of a new school stage rather than in later years when the differences between pupils are manifest and very difficult to change.

If we apply Bloom's arguments to the Swedish school system we will find that the "same" instruction, without allowing for a differentiation in amount of time, will lead to larger differences in skills and knowledge at the end of compulsory schooling than at the beginning of it. The effect will presumably be that some pupils will learn practically nothing from the school instruction. They will leave school feeling worthless, with a damaged self confidence and bad prospects for the future. Those pupils who already at the beginning have difficulties to adjust to school and find the content meaningless and incomprehensible will, when they get to the next stage in their education lack the basic skills necessary to understand the continuity of educational content. These pupils will also to a large extent be prevented from further educational pursuit. The reasons why pupils from the beginning experience these difficulties, could be, for instance, late matu-

ring, lack of ability for theoretical studies and lack of parental support.

The recommendation given by Bloom is that "*inequality of treatment* may be needed, at least at certain stages of the learning process, if children are to attain equality of learning outcomes" (op.cit., p. 215).

Individual development

The adjustment of school organization to the individual development of each pupil has been propagated by alternative pedagogics. They have also claimed that the pupils in collaboration with the teachers must actively create their own work and be a part of and contribute to a change in society (Kunskap - insikt - frigörelse, 1975; Sjöberg, 1977). Some teachers in the Swedish schools follow these suggestions and try to educate their pupils according to individual needs. Since this implies that the organizational demands at school must be disregarded, a lot of courage and belief in this approach is needed to overcome the difficulties. It could also be expected that this kind of educational policy, when practised, will create problems if it is incompatible with societal demands. If, for instance, differences are looked upon and treated as assets in school but at the same time theoretical knowledge and intellectual abilities are overrated in society, it could lead to conflict for the individual when leaving school.

The discussion presented here leads to the conclusion that both the achievement of basic skills at school and the encouragement of individual development presupposes an *unequal* treatment of pupils. It could therefore be questioned why the Swedish compulsory school system tends to be so uniformly organized. The answer is of course the basic issue of equality. This is, however, incompatible with the values and status connected with different occupations in the society. If theoretical ability and achievement are overrated and have a higher status than other abilities, a large group of pupils will fail in this school system.

Husén (1977) has discussed this dilemma in his book "Equality through education?", and he also compared different educational systems in this respect (Husén, 1978). He maintains that equality and meritocracy basically are incompatible and that meritocracy is an integrated part of modern industrialized society. This type of society, whether capitalistic or socialistic, must for its existence encourage special talents such as intellectual ability. Inevitably, there will be inequality in the sense that some will not be able to compete on these conditions.

Sjöstrand (1970) has analysed the meaning of the two concepts "freedom" and "equality" from the view-points of politicians, unionleaders, researchers and educators. The inherent contradiction between the two concepts is stressed. If freedom for everyone is emphasized it will often result in more inequality and if equality is emphasized a certain restriction of freedom will often be necessary. Sjöstrand's conclusion regarding this dilemma is that the aim of research must be to gather knowledge helping politicians to balance the two extremes.

This report presents results having implications for the discussion of the above-mentioned dilemma. The main content of the report concerns heredity-environment interaction and correlation both at the individual and at the group level. Interactional and correlational effects have in earlier twin studies been interpreted as genetic variance (Elston & Boklage, 1978) and often contributed to a pessimistic view on the effectiveness of environmental manipulation. This report has demonstrated the existence of interactional and correlational effects. Individuals are affected and react to environmental influences on the basis of their inherited characteristics. It is therefore necessary to pay attention to such influences. It can also be maintained, on the basis of the results presented here, that the magnitude of interactional and correlational effects to some extent can be manipulated by varying environmental permissiveness or restrictedness. In a more restricted situation interactional and correlational effects will thus tend to contribute less to variation whereas in a free and permissive situation such effects tend to be substantial.

There seem to be a belief behind the Swedish school reforms that equality of treatment would lead to reduced differences between individuals and also between different social groups in society. Equal access to equal educational treatment is supposed to contribute to a more democratic and equal society. Results from the twin studies reported here may suggest that equality of treatment together with a reduction of societal pressure could have the opposite effect. Instead of reducing differences between children, the differences tend to increase as an effect of the uniform schooling. Furthermore this increase of differences is related to social background, which will lead to a widening gap between social groups with respect to what is taught at school.

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SUPPLEMENT

The supplement has been removed because it contains reprints of nine of the journals cited in the References section. (copyrighted material)